SRF Cavity Activities at DESY

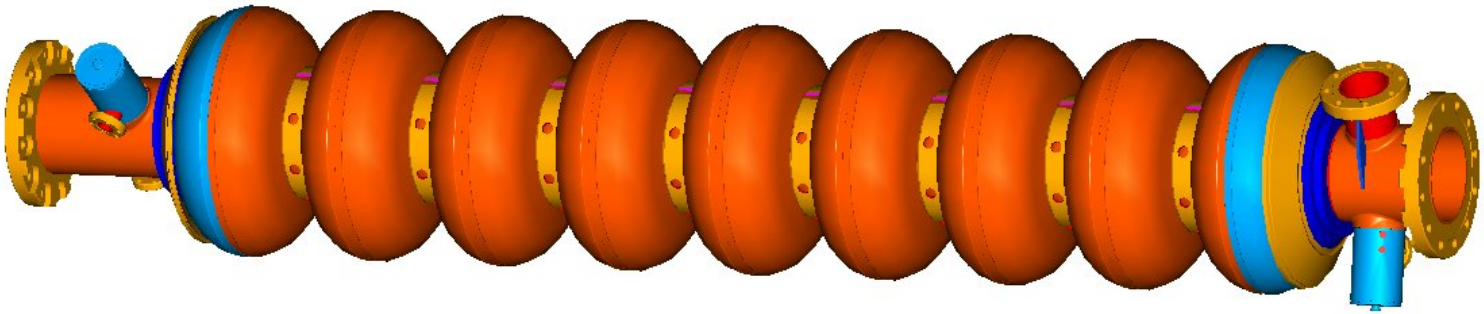
Detlef Reschke for all involved DESY colleagues

TTC Meeting, 25. – 28. September 2006

- Nine-cell cavities
  - Fourth production (Zanon cavities)
  - Large grain nine-cells
  - Upcoming fifth production
- Test cavity program for XFEL (single-cells)
  - Large grain activities
  - DESY inhouse production
- CARE activities

Fourth cavity production: Introduction

- Fourth cavity production series:
  - 30 nine-cells fabricated by Zanon company
    (incl. 3 prototypes with irregularities during fabrication)
  - 15 cavities of Teledyne Wah Chang Nb; 14 cavities of Tokio Denkai Nb;
    1 mixed cavity
  - delivery from mid 2004 to end of 2005
- "Standard" cavity preparation:
  i) first EP of 150µm, outside etching, 800C firing, final EP of (40 - 50) µm
  ii) first EP of 150µm, outside etching, 800C firing, final BCP of 10µm
  => 4 of 8 cavities done



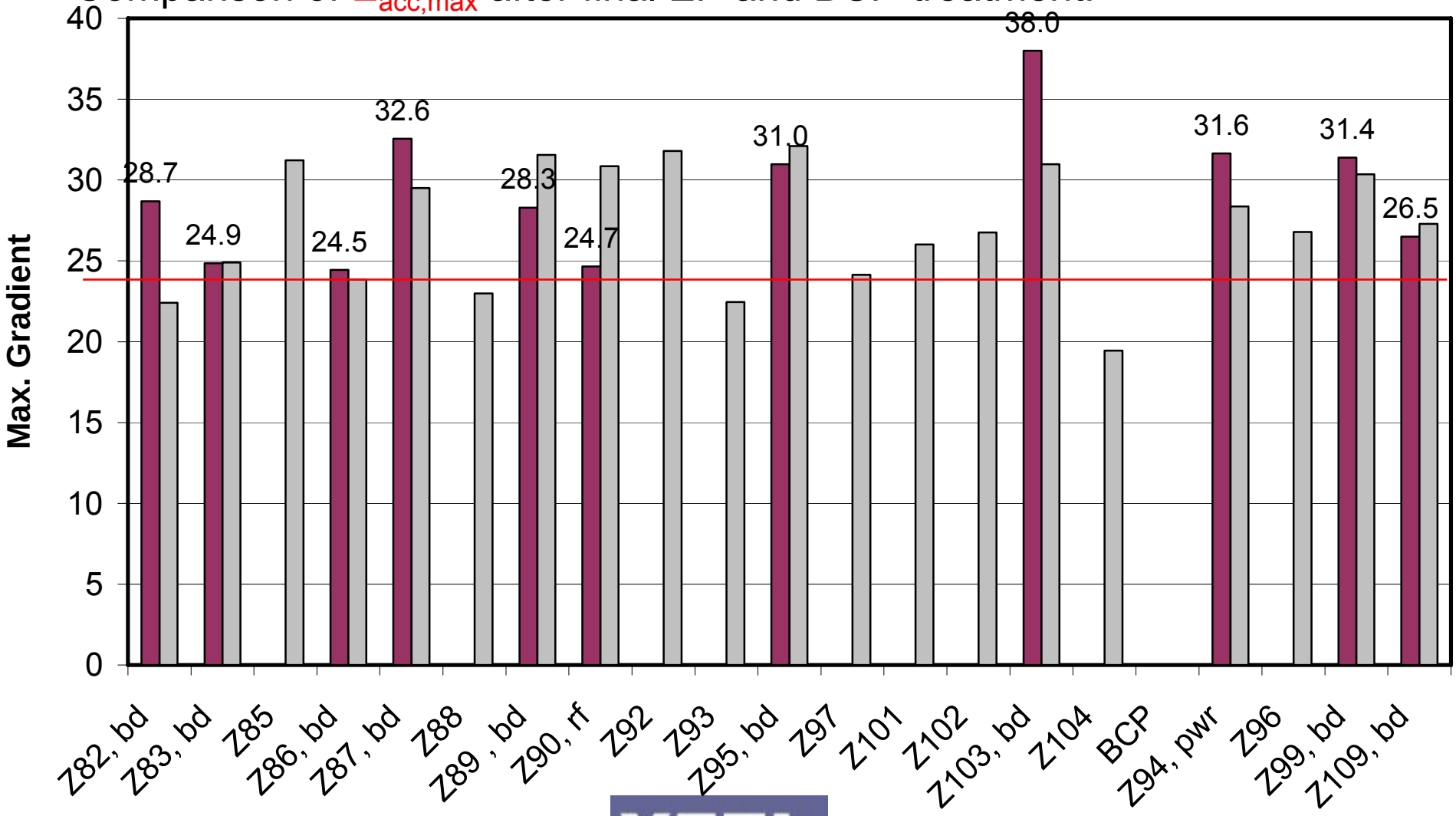
Fourth cavity production: Introduction II

- Exceptions in cavity processing:
  - Z82 – Z84 (prototype cavities) got 1350C titanisation
  - partially 120C bake is skipped due to lack of time (=> module completion)
- Cavity Testing:
  - 20 cavities vertically tested
  - 7 cavities Chechia tested; 2 under preparation
  - many delays caused by infrastructure problems

- Remark:
  - Z84 not included due to multiple Q-disease !!
  - Z82 + Z83 after 1350C not included

Fourth cavity production: $E_{acc,max}$

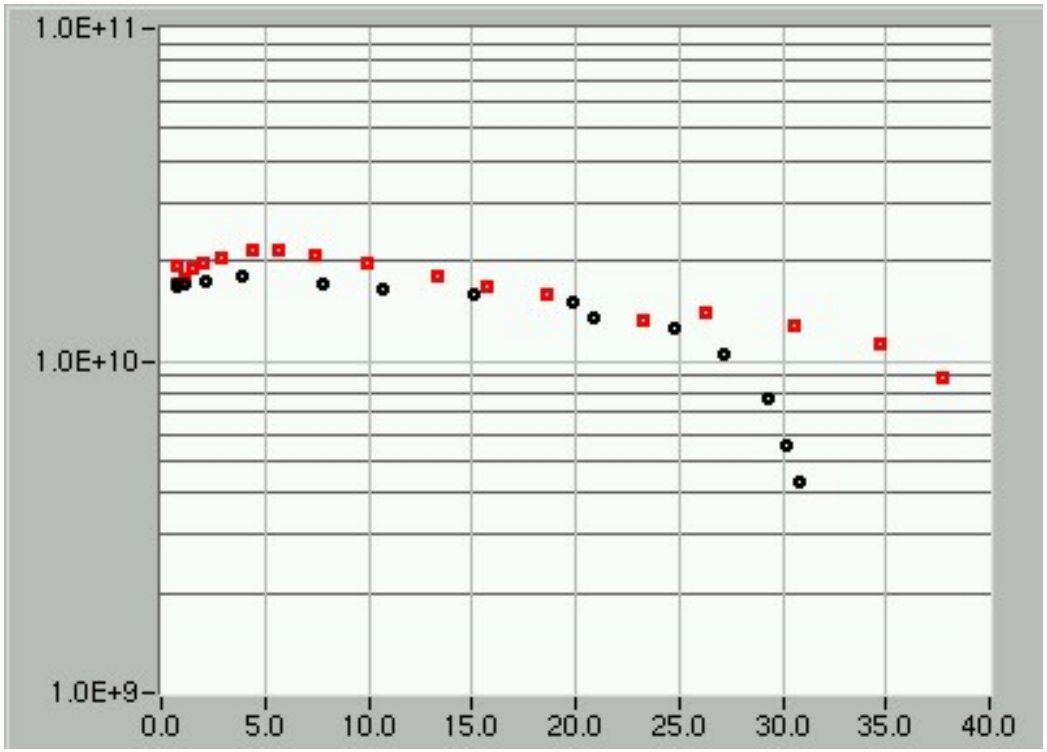
- Comparison of $E_{acc,max}$ after final EP and BCP-treatment:



Fourth cavity production: Z103

- Best $E_{acc,max}$ last week
- Z103 tested after EP + 800C treatment:

  E_{acc} = 38 MV/m @ Q_0 = 9 ·10^9; strong FE (>25 / 30) , lim. by Quench



Q(E) - curve at 2K before and after bake

Fourth cavity production: Results after **EP**

- Analysis of 16 cavities after final EP + **before 120C bake** :
- Maximum gradient $E_{acc,max}$
  - 9 cavities limited by quench (bd)
  - 6 cavities limited by power
  - 1 cavity by FE (extremely high x-ray level)

  => 7 of 9 cavities limited by quench below 25 MV/m, with some quenches maybe field emission induced e.g. Z82, test1 !!!

- Analysis of 8 cavities after final EP + **after 120C bake** :
- Maximum gradient $E_{acc,max}$
  - 7 cavities limited by quench (bd) between 24,5 MV/m and 38 MV/m
  - 1 cavities limited by rf-problems

  => 3 cavities limited by quench just below 25 MV/m !!
- Only 1 of 7 cavities exceed x-rays of 10^{-2} mGy/min !!

=> Often no improvement after 120C bake due to quench limitation!!

Fourth cavity production: Results after **BCP**

- final BCP of 10µm after 800C + 150µm EP **before 120C bake**
- Intended to treat and test 8 cavities => 4 cavities done

- Maximum gradient $E_{acc,max}$
  - 3 cavities limited by quench (bd) at 27-28 MV/m
  - 1 cavity limited by power at 30MV/m

- 3 cavities **after 120C bake** (one cavity not tested):
- Maximum gradient $E_{acc,max}$
  - 2 cavities limited by quench at 27 MV/m and 31 MV/m
  - 1 cavity limited by power at 31 MV/m

=> Q-slope not cured completely at 120C – 135C for 48h

Fourth cavity production: Quench locations

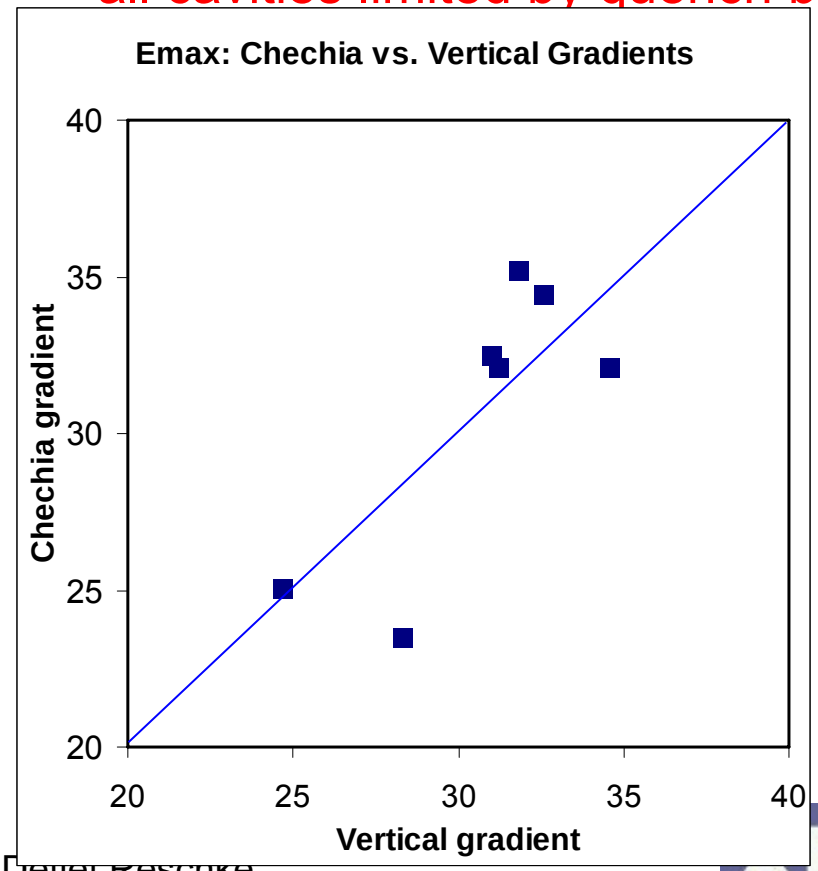
- Table of quench locations :

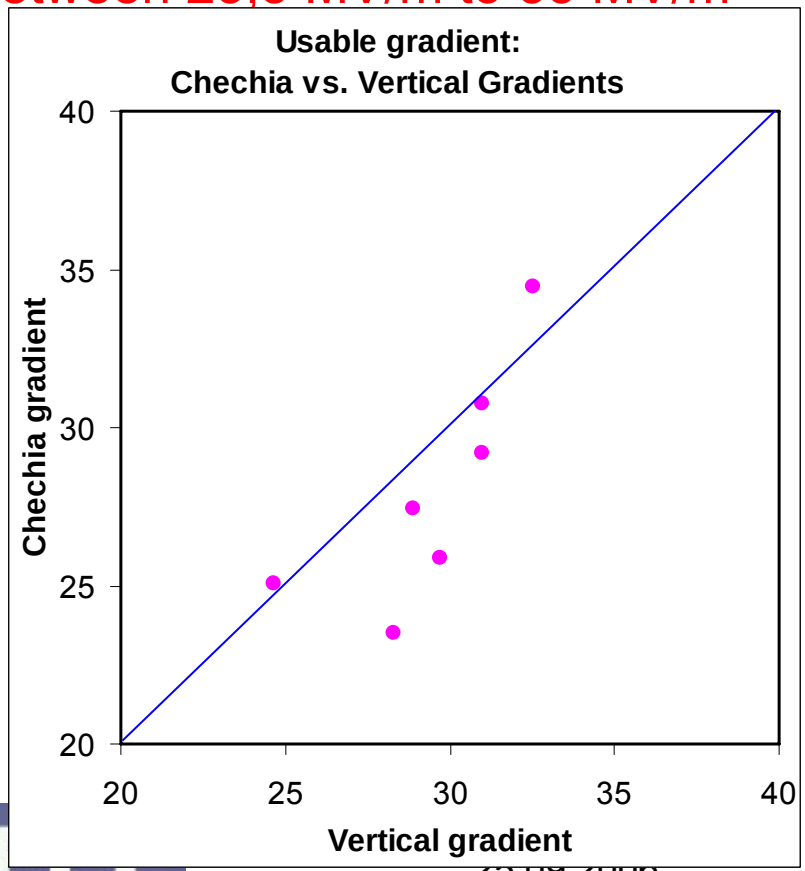
Cavity	Gradient	Quench location	Preparation + remark
Z82, test 2	28 MV/m	cell 9, equator	EP + 127C; no FE
Z83, test 2	25 MV/m	cell 1 with two hot areas i) equator; ii) upper cup	EP + 127C; no FE
Z85, test 2	33MV/m	cell 3, equator area; but highest dT 2 resistors off the equator ??	EP + 124C; some FE
Z87, test 1	29 MV/m	cell 4, lower cup; far off equator	EP; no FE
Z89, test 2	28 MV/m	7/9pi-mode(!): cell 5, lower cup, hot area from equator to iris ??	EP + 120C; some FE
Z94, test 2	28 MV/m	cell 3, upper cup, 3 resistors off the equator	BCP; few FE

Fourth cavity production: Chechia-Results

- Up to now 7 cavities Chechia-tested (incl. Z83 after 1350C-heat treatment)
- All cavities EP-processed with 2 cavities not baked => bad Qo in Chechia
- Maximum gradient $E_{acc,max}$

  => all cavities limited by quench between 23,5 MV/m to 35 MV/m





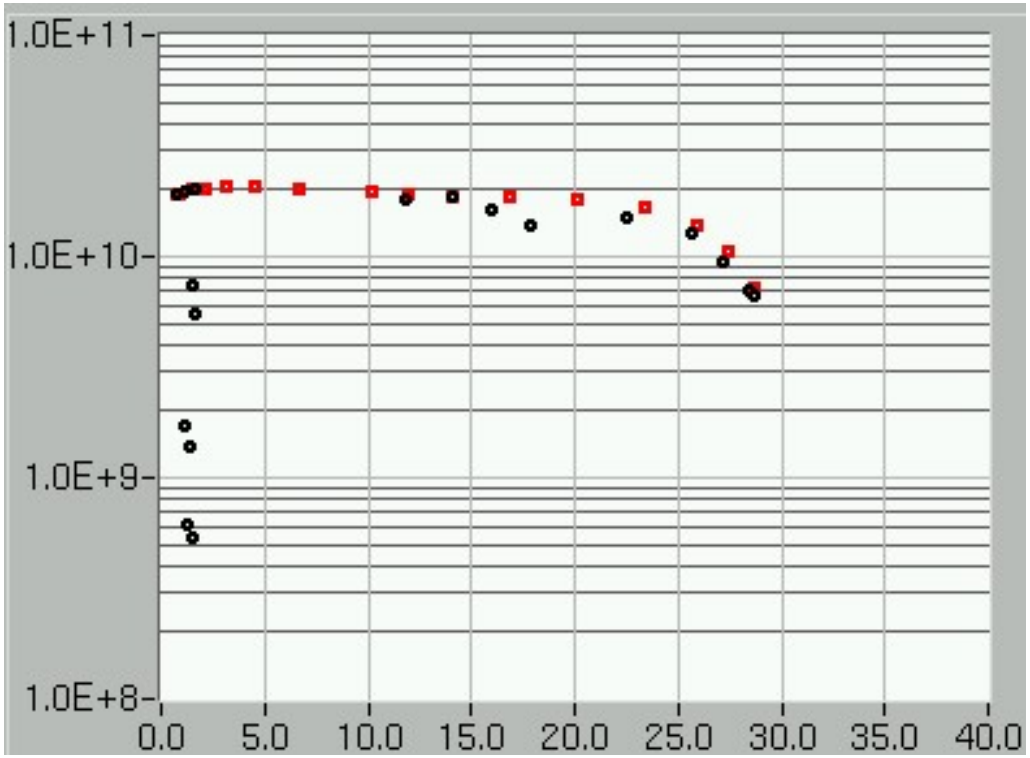
Fourth cavity production: Summary

- Broad scatter of $E_{acc,max}$ (also usable gradient) in vertical and Chechia tests !!!
- EP final treatment: 7 of 16 tested cavities are quench limited below 25 MV/m !!
  - partially “real” quench; partially FE induced
  - T-mapping of bad cavities missing
  - 120C-bake after EP: Often no improvement in E_{acc} due to quench limitation
- BCP final treatment: 4 cavities between 27 and 31 MV/m
  - 120C-bake after BCP: Cure of Q-slope not complete?? => more tests
- Many cavities show significant field emission => preparation process not reproducable !!
- Next steps: - Completing of vertical tests of remaining cavities
  - Re-treatment, measurement + analysis of “bad” cavities
- Assembly of module 7 with accepted cavities

Nine cell cavities of large grain niobium

- 3 cavities built of Heraeus Nb cut from ingot with RRR ~ 500 at Accel
- AC114 tested after BCP + 800C treatment:

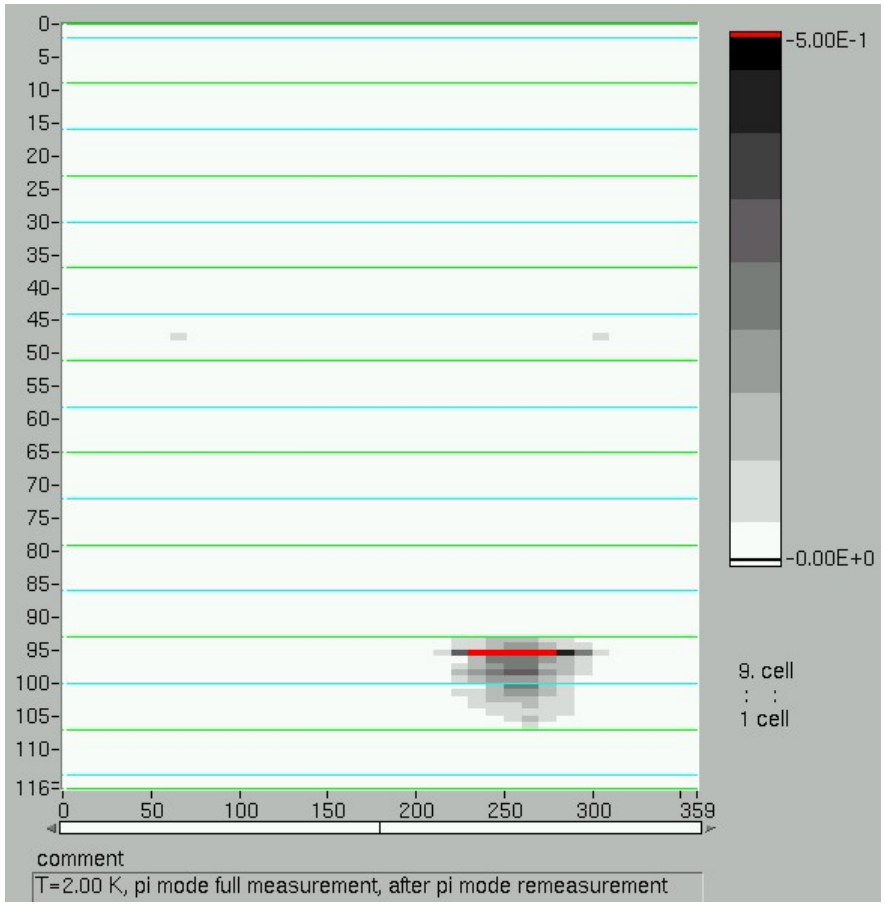
  E_{acc} = 28,7 MV/m @ Q_0 = 7,3 ·10^9; strong FE (>18 / 23) , lim. by Quench => FE induced ??? ; LPP at 2MV/m observed; no Q-disease

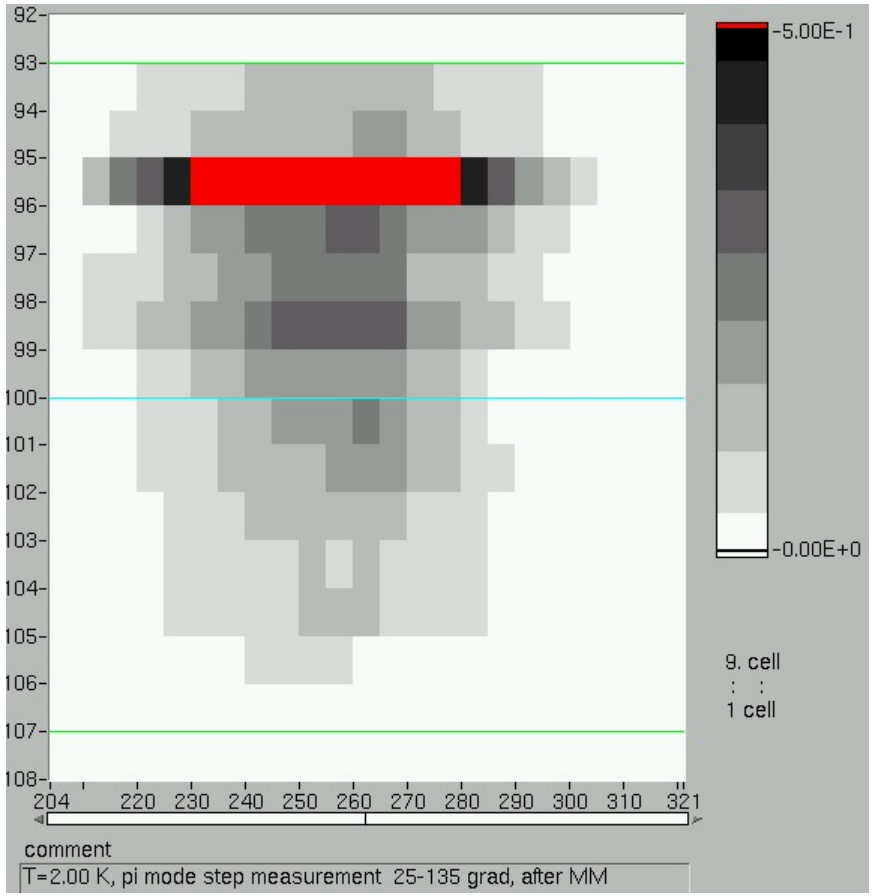


First and final Q(E) - curve at 2K

Large grain nine-cell AC114 test 1: T-Maps

- T-Maps at 2K during Quench (after mode measurement):





=> Quench in cell 2, upper cup, between iris and equator

=> FE- induced quench??

AC114: Mode measurement of test 1

			Best CW-Test						
Cavity	Prod No	Cells	BCP/EP Cavity	CW-Test Date	Max. Eacc	Qo at Max. Eacc	Limit	FE Onset	Eacc at Q=1e+10
AC114	5	ALL	BCP	07-Jul-06	28.74	6.5E+09	bd	17.50	27.22
		1&9			32.36		bd		
		2&8			31.68		bd		
		3&7			36.03		bd		
		4&6			32.89		bd		
		5			32.98		bd		

- All cells are quench limited
- All cells have higher max. E_{acc} than pi-mode

=> inconsistency caused by influence of FE

Fifth nine-cell production

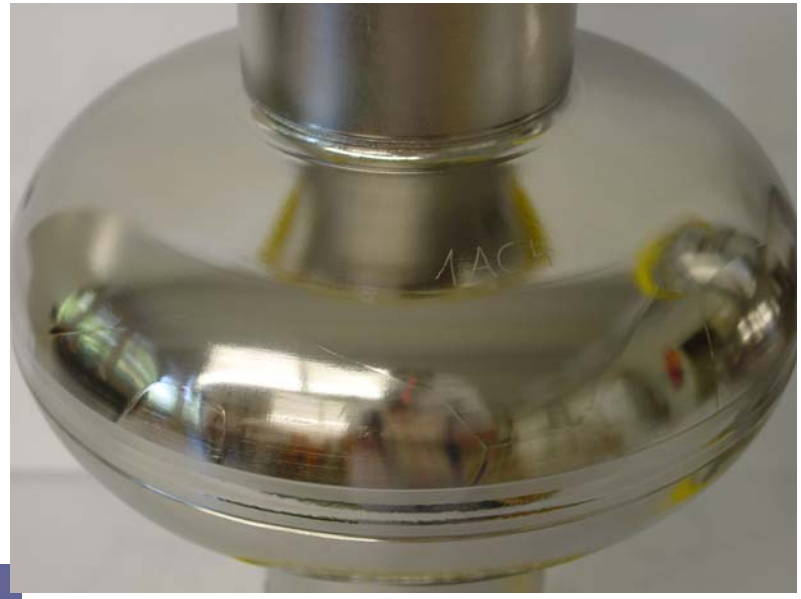
- Material:
  - 594 Nb sheets delivered by Tokyo Denkai
  - all sheets accepted according to DESY spec.
  - all sheets eddy current scanned with 21 suspicious (3,5%) => re-scanning and SQUID-analysis
  - shipping to Accel and Zanon in July 06
- Fabrication:
  - Contract split with 15 cavities each to Zanon + Accel
  - Production of cups starts now
  - Zanon:
    delivery of first cavities end of Nov 06; production complete Feb 07
  - Accel:
    delivery of first cavities Feb 07; production complete Jun 07

XFEL test cavities: Large grain single-cells

- Four single-cell cavities (+ three nine-cell cavities) fabricated at Accel Co. of “large grain”-Nb by Heraeus with RRR = 500 (two Nb batches/ingots)
- DESY in-house production of large grain single-cells under preparation
- Two mono-crystal cavities fabricated at Accel by CBMM (1AC6) and Heraeus niobium (1AC8: prepared and tested by Peter Kneisel)

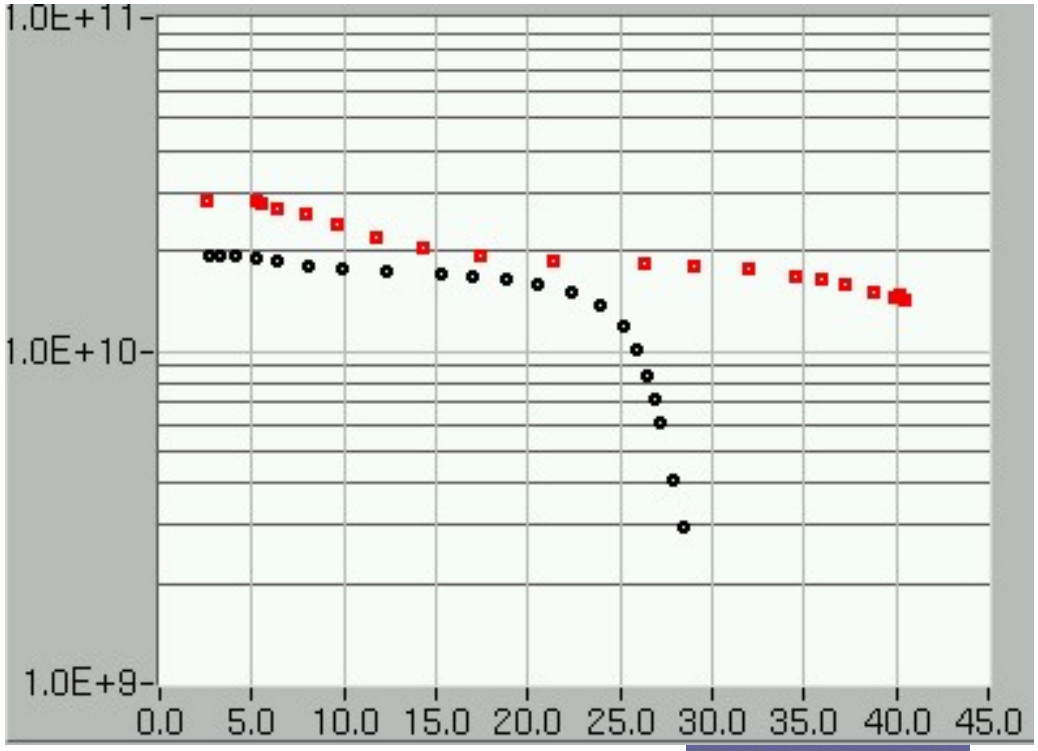
- significant mechanical problems during deep-drawing (shape + tolerances !!!)

- First tests at DESY after EP processing
- Full comparison of EP vs. BCP final treatment ongoing



XFEL test cavities: Large grain single-cells

- Comparison of EP vs. BCP final treatment:
- - EP treatment of single-cells at Henkel Co.
  - BCP treatment of single-cells at Accel (or DESY)
  - final HPR, assembly, bake at DESY
- Best result of 1AC3 after 150µm EP, 800C, 40µm EP + 120C, 48h bake :



Q(E)- curves at 2K
before and after bake

XFEL test cavities: Large grain single-cells

		1AC3	1AC4	1AC5 spun cup	1AC7	1AC6 mc	1AC8 mc (JLab)
EP before bake	Eacc	28,4 (FE)	29 (pwr)	-	-	-	-
	Qo	3e9	3e9	-	-	-	-
+ bake		34,4 (FE)	37,2 (BD)	29,3 (BD)	-	-	-
		4e9	6,3e9	1,3e10	-	-	-
+ re-HPR		41 (BD)	Dry-ice	-	-	-	-
		1,4e10		-	-	-	-
+ BCP(40-50um or only BCP)		30,5 (pwr)	30 (pwr)	next test	25,2 (BD)	21,5 (BD)	37,5 (BD)
+ HPR		2,2e9	2,2e9		1,5e10	1,8e10	
+ bake		28,5 (BD)	28,2 (BD)		-	-	
		1,2e10	1,2e10		-	-	
+ BCP (40 µm)		next test					
+ HPR							
+ EP (100µm)					next test	29,4 (pwr)	
+ HPR						2,2e9	

XFEL test cavities: Large grain single-cells

- Comparison of EP vs. BCP final treatment (ctd.):
- Preliminary results:
  - Two cavities degraded after add. BCP-treatment (- 11MV/m and -8 MV/m)
  - Mono-crystal single cell 1AC6 improved after EP (+ 8MV/m)
  (test after bake still missing)

- Contradiction to excellent BCP results at JLab???

- Full cycles (EP → BCP → EP) or (BCP → EP → BCP) for all large grain cavities on the way

XFEL test cavities: DESY in-house production

- Objects of the program:

  - Qualification of further niobium vendors
    => Plansee, Ningxia, Cabot, Giredmet

  - Qualification of modified welding procedure

  - Development of dry-ice cleaning as additional cleaning process (CARE,..)

  - Check + optimisation of “120C-bake” parameters

  - Comparison of EP processes at Henkel and DESY

  (- s.c. photo cathode gun cavity)

XFEL test cavities: Further Nb vendors

- Plansee :
  - Three cavities fabricated of Heraeus/Plansee Nb with RRR ~ 300
  - First result of 1DE16 after 800C, EP + bake:

    E_{acc} = 28,5 MV/m @ Q_0 = 2,5 ·10^9; FE (>19 / 25MV/m) ; limited by pwr
  - Two cavities send to Henkel for EP
- Ningxia:
  - Three cavities fabricated of chinese Ningxia Nb with RRR ~ 300
  - Cavities under preparation

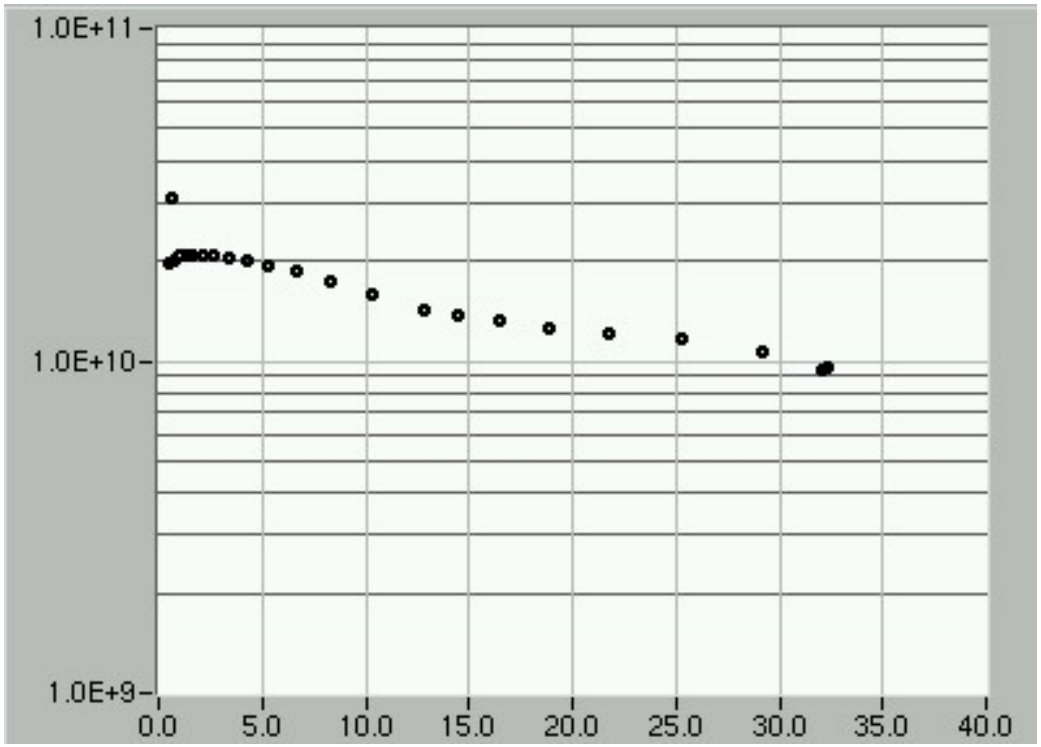
XFEL test cavities: Further Nb vendors

- Cabot :

  - Two cavities fabricated in-house of Cabot Nb with RRR ~ 230 !!

  - Preparation: >100µm BCP@Accel, 800C firing, >100µm EP@Henkel, (HPR, 130C bake)

E_{acc} = 33 MV/m @ Q_0 = 9,5 ·10^9; low FE(>30 / -MV/m) ; limited by bd



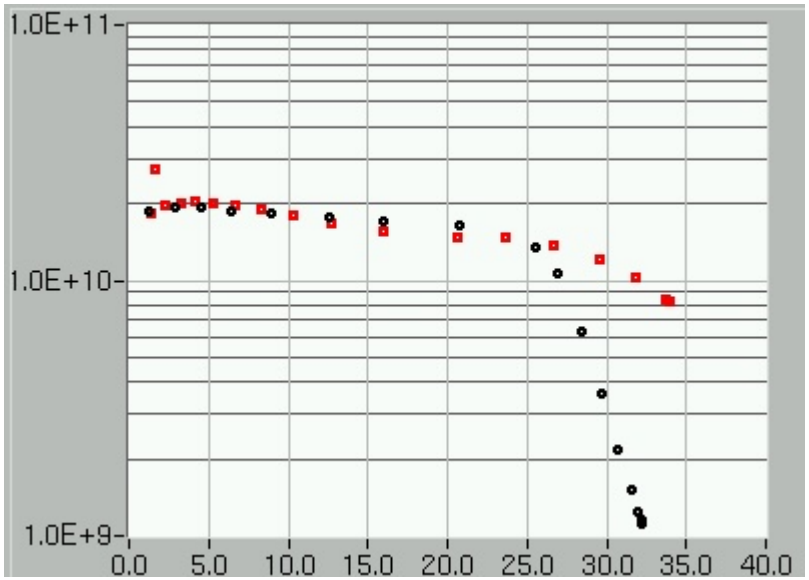
Q(E)- curve at 2K after bake

XFEL test cavities: Further Nb vendors

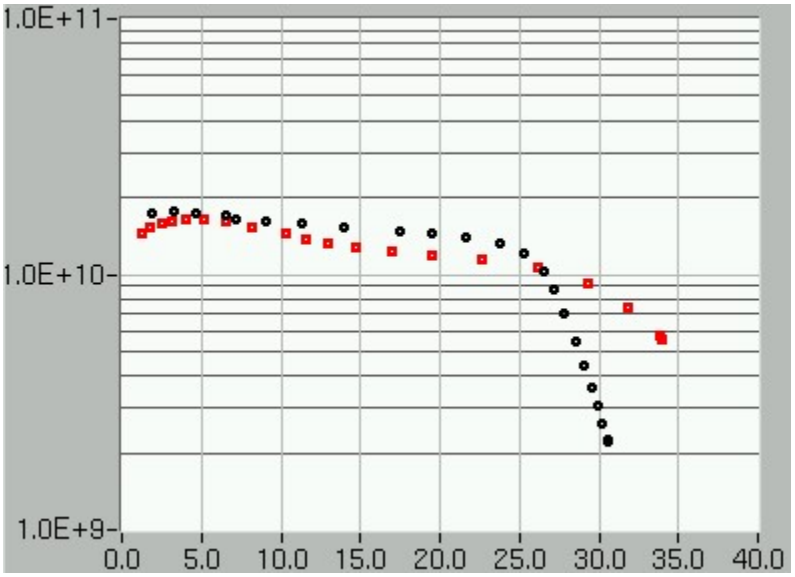
- Giredmet/ITEP:

  - Three cavities fabricated in-house of russian Giredmet Nb RRR > 600 (2x completed)

  - Preparation: 150µm EP, 800C firing, 40µm EP, HPR, (add. HPR or add. 130C/136C bake) => Qualification successful!!



Q(E)-curves of 1DE4 before and after bake (some FE present before and after bake)



Q(E)-curves of 1DE5 before and after bake (some FE present before and after bake

XFEL test cavities: Modified weld preparation

- Up to now: max 8h between final etching of weld area and EB welding ("8h – rule")
- Modification of present spec for welding preparation during cavity fabrication:

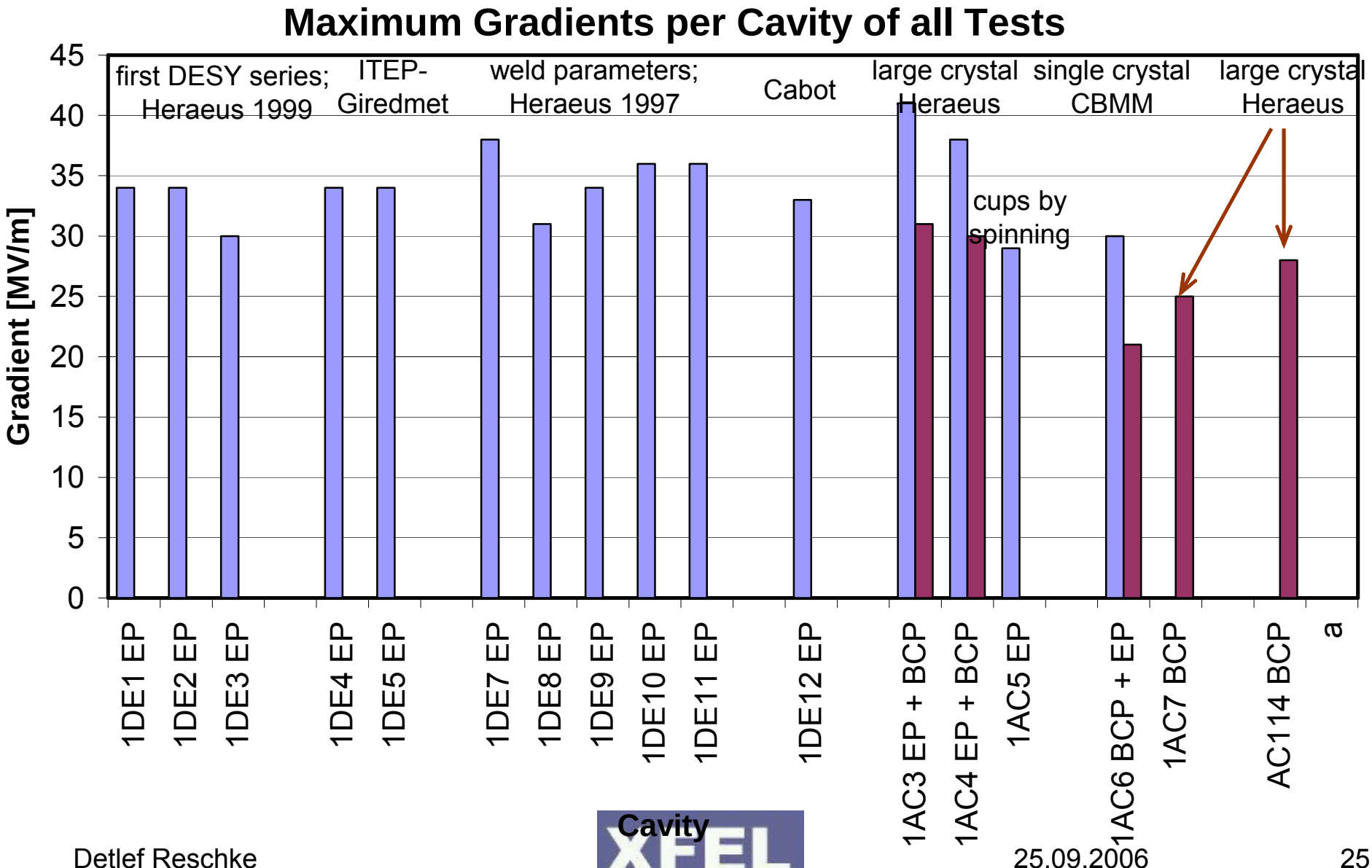
  - 1x reference cavity: max 8h between final etching of weld area and EB welding
  - 2x cavities with 168h storage under vacuum of components after final etch of weld area
  - 2x cavities with 168h storage under nitrogen atmosphere of components after final etch of weld area

XFEL test cavities: Modified weld preparation

- Results:

		Reference cavity	Vacuum storage for 168h		Nitrogen storage for 168h	
		1DE7	1DE8	1DE9	1DE10	1DE11
EP + HPR + bake (+HPR)	Eacc:	38,2 (BD)	31,3 (BD)	33,8 (BD)	34,7 (BD)	35,8 (BD)
	Qo:	1,1e10	1,5e10	1,4e10	1,6e10	2,6e9
						FE present

XFEL test cavities: Summary



CARE activities

- CARE (Coordinated Accelerator Research in Europe):
  - contains 3 JRA's (Joint Research Activities)
    - SRF => Research and Development on Superconducting Radio Frequency
    - PHIN => Charge production with Photo Injectors
    - HIPPI => High Intensity Pulsed Photon Injector
    - NED => Next European Dipol

  - and 3 networks
    - ELAN => Electron Linear Accelerator Network
    - BENE => Beams for European Neutrino Experiments
    - HHH => High Energy, High Intensity Hadron Beams

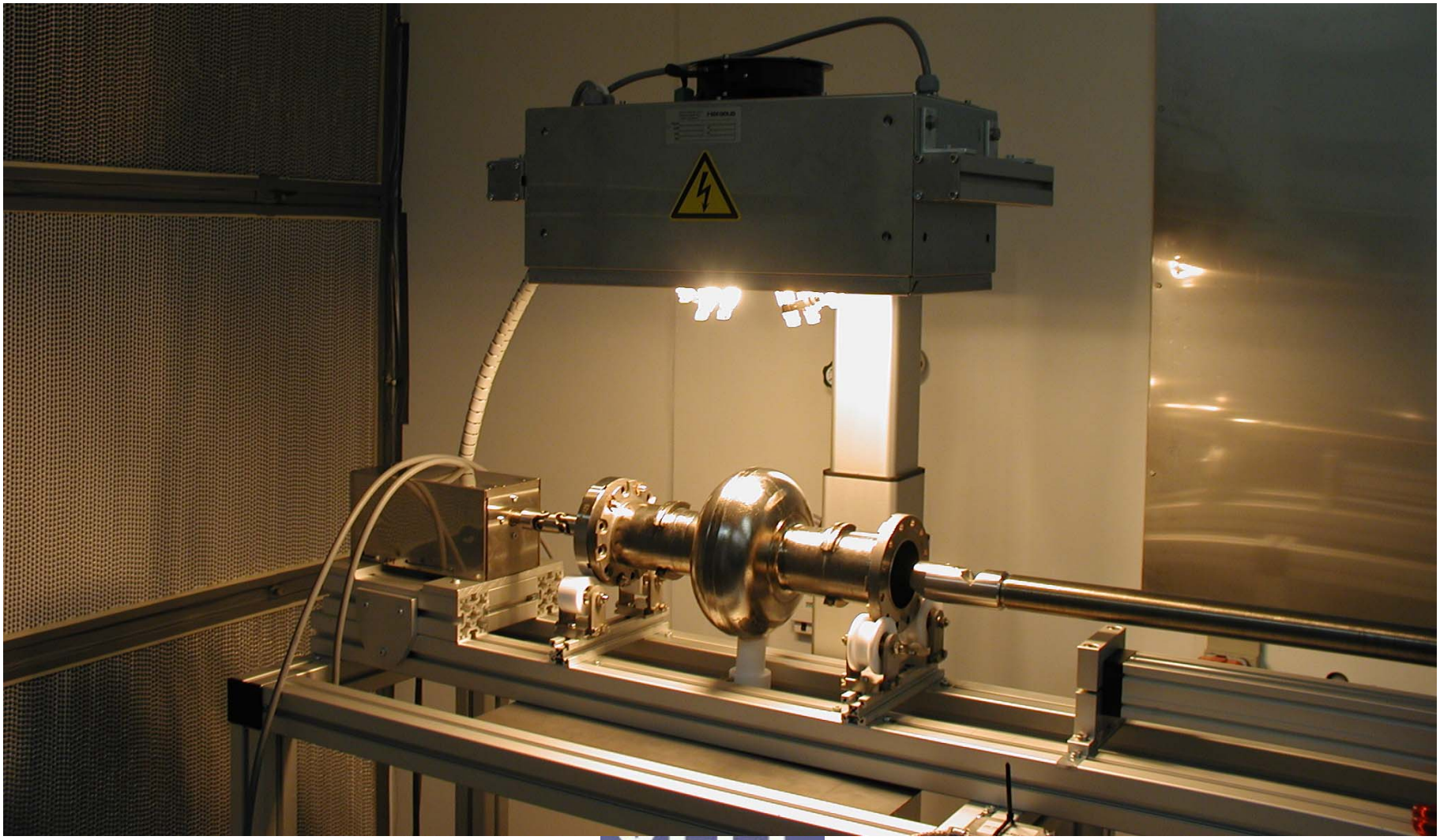
- All activities fill more than one workshop ….

CARE activities:

Work package / task	Work package / task leader	Institution
2 Improved Standard Cavity Fabrication (ISCF)	***P.Michelato***	**INFN Mi**
2.1 Reliability analysis	L. Lilje	DESY
2.2 Improved component design	P.Michelato	INFN Milano
2.3 EB welding	J. Tiessen	DESY
3 Seamless Cavity Production (SCP)	***W.-D. Moeller***	**DESY**
3.1 Seamless cavity production by spinning	E. Palmieri	INFN LNL
3.2 Seamless cavity production by hydroforming	W. Singer	DESY
4 Thin Film Cavity Production (TFCP)	***M. Sadowski***	**IPJ**
4.1 Linear arc cathode	J. Langner	IPJ
4.2 Planar arc cathode	S. Tazzari	INFN Roma2
5 Surface Preparation (SP)	***A. Matheisen***	**DESY**
5.1 EP on single cells	C. Antoine	CEA
5.2 EP on multicells	N. Steinhau-Kühl	DESY
5.3 Automated EP	E. Palmieri	INFN LNL
5.4 Dry ice cleaning	D. Reschke	DESY
6 Material Analysis (MA)	***E. Palmieri***	**INFN LNL**
6.1 Squid scanning	W. Singer	DESY
6.2 Flux gate magnetometry	M. Valentino	INFN LNL
6.3 DC field emission studies of Nb samples	X. Singer	DESY
7 Couplers (COUP)	***A. Variola***	**IN2P3-Orsay**
7.1 New proto-types	L. Grandsire	IN2P3-Orsay
7.2 Titanium-nitride coating system	L. Grandsire	IN2P3-orsay
7.3 Conditioning studies	P. Lepercq	IN2P3-Orsay
8 Tuners (TUN)	***P. Sekalski***	**TUL**
8.1 UMI Tuner	A. Bosotti	INFN-Milano
8.2 Magnetostrictive Tuner	A. Grecki	TUL
8.3 CEA Tuner	P. Bosland	CEA
8.4 IN2P3 activities	M. Fouaidy	IN2P3 Orsay
9 Low Level RF (LLRF)	***S. Simrock***	**DESY**
9.1 Operability and Technical performance	S. Simrock	DESY
9.2 Cost and reliabilty	M. Grecki	TUL
9.3 Hardware technolgy	R. Romaniuk	WUT-ISE
9.4 Software technology	Jezynski	WUT-ISE
10 Cryostat Integration Tests	***B. Visentin***	**CEA/DSM/DAPNIA**
11 Beam Diagnostics (BD)	***M. Castellano***	**INFN-Frascati**
11.1 Beam position monitor	C. Simon	CEA/DSM/DAPNIA
11.2 Emittance monitor	C. Magne	CEA
11.3 HOM beam position monitor	O. Napoli	IN2P3-Orsay

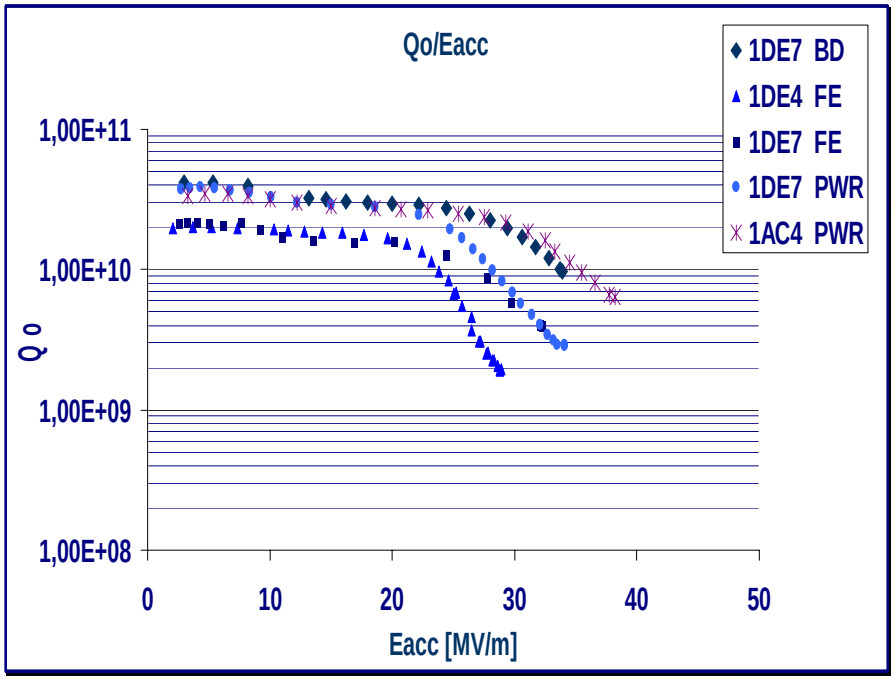
CARE activities: Dry-ice cleaning

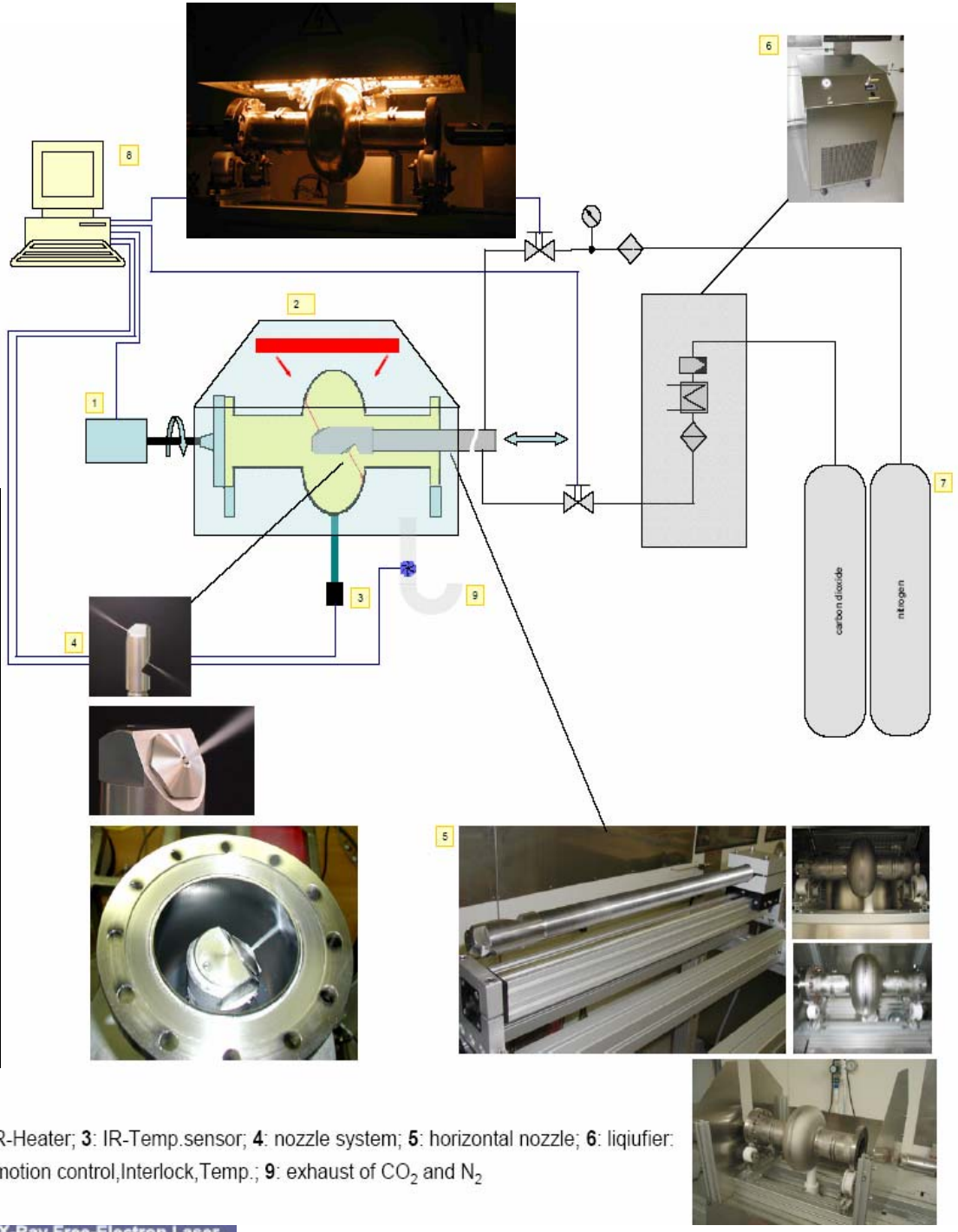
- Set-up:



CARE activities: Dry-ice cleaning

- Prototype for horizontal cleaning under successful commssioning

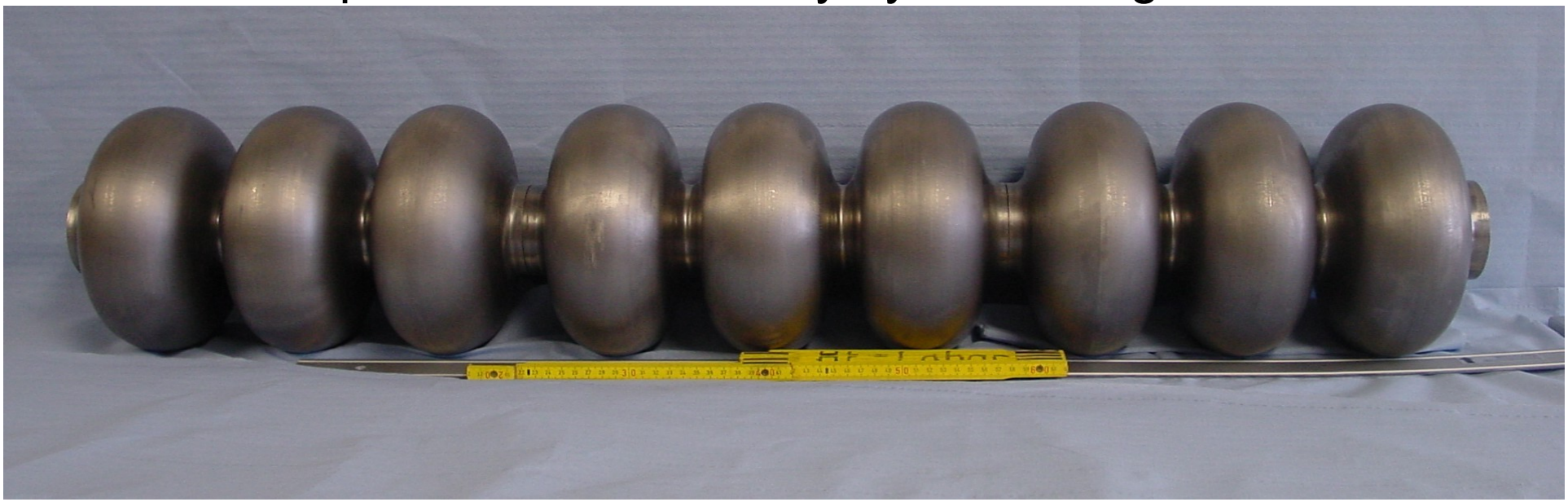




Explanation:
1: motor; **2**: IR-Heater; **3**: IR-Temp.sensor; **4**: nozzle system; **5**: horizontal nozzle; **6**: liqiufier: **7**: Gases; **8**: motion control,Interlock,Temp.; **9**: exhaust of CO_2 and N_2

WP3.2 Seamless by Hydroforming (W.Singer)

Seamless cells for 9-cell cavity (three three cell units) have been produced at DESY by hydroforming



Fabrication of a seamless cavity (without equator welds) is in work at the industry and includes following steps:

- Fabrication of the long and short end groups connected with three cell units
- Machining, preparation and welding of three units together in a 9 cell cavity (two iris welds done from outside)
- Machining, preparation and weld on of the stiffening rings

XFEL
X-Ray Free-Electron Laser